INERTIAL CONFINEMENT FUSION

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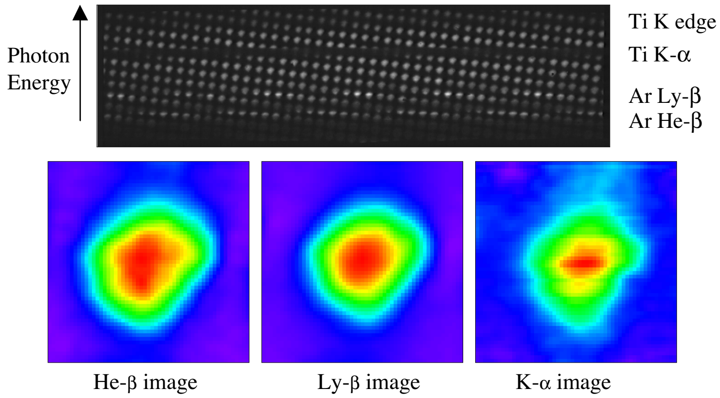
Monochromatic X-Ray Imaging—a New Tool for Diagnosing Plasma Conditions.

Multispectral imaging is a powerful tool for the quantitative diagnosis of three-dimensional structure in plasmas. This technique uses multiple monochromatic x-ray images, obtained over a band of x-ray wavelengths, to infer information about temperature and density gradients within the plasma. We recently implemented a multispectral x-ray imaging diagnostic on the OMEGA laser at the University of Rochester's Laboratory for Laser Energetics (UR-LLE), and used it to obtain data on temperature and density gradients within indirect-drive implosion cores for the first time. We also obtained preliminary data on areal density modulations within the pusher. The diagnostic, the MMI2, uses an array of pinholes mounted on the target to produce hundreds of individual core images; it is modeled after a concept developed at UR-LLE. A multilayer Bragg mirror placed between the pinhole array and the CID (charge-injection device) detector effectively monochromatizes the individual images at an x-ray energy related to the local angle of incidence upon the mirror. The result is an x-ray spectrum made up of individual core images. The images provide information about spatial structure, and the spectral dispersion provides temperature and density information.



Typical MMI2 data from an indirect-drive implosion of a capsule containing Ar-doped D_2 gas surrounded by Ti-doped plastic. Core density and temperature gradients can be inferred from comparison of images obtained in the He-β and Ly-β spectral bands, while pusher areal density modulations can be inferred from comparison of images taken within the Ti K-α band to images taken just outside this band.

Simulations Show Value of Imaging Down-Scattered Neutrons on NIF Ignition Implosions.

For some years, efforts have been under way to image the neutrons emitted from ICF implosions. These images have utilized the 14-MeV neutrons from the DT reaction and have provided an image of hot burning fuel. Recent simulations have explored the value of imaging the down-scattered neutrons that are produced by scattering at approximately 90° in the relatively cool high-density fuel surrounding the central hot spot. Imaging the high-density fuel is likely to be very valuable in attempts at ignition, since the sources of nonuniformity in the implosion often result in variations in the density and location of this material. The nature of these variations will be important indicators of the source of nonuniformity. Figures 1, 2, and 3 illustrate the value of this technique. All three are simulated neutron images, with 10-µm resolution, of a baseline cryogenic ignition implosion. Figures 1 and 2 are of the same implosion, which had a sixth order Legendre polynomial perturbation. The perturbation was large enough to prevent ignition, with yield 50 kJ instead of the nominal 17 MJ. Spikes penetrated the hot spot along the hohlraum waist and at 30° from the axis. Figure 1, showing the image of the primary 14-MeV neutrons, shows little of this structure; only the innermost part of the hot spot burned enough to produce significant brightness. Figure 2 shows the image of 6- to 7-MeV neutrons and clearly shows the high-density DT features on the waist and surrounding the axis. Figure 3 shows another simulation in which the sign of the perturbation was reversed, so that the spikes are penetrating along the pole and at 60°. The high-density spikes are clearly evident, and the complementarity to Figure 2 is striking.

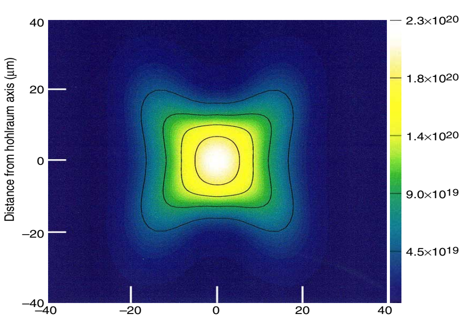


Figure 1. Image of 14-MeV primary neutrons from a simulated implosion of a NIF ignition target, with a P_6 perturbation causing spikes along the hohlraum waist and 30° from the axis. The perturbations were large enough to prevent ignition, bringing the yield down from 17 MJ to 50 kJ.

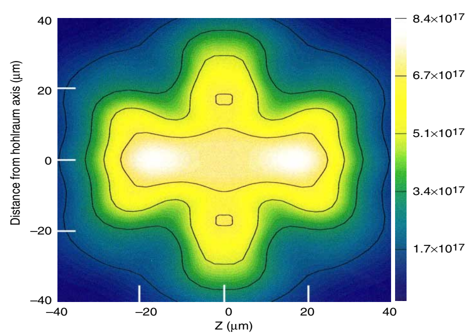


Figure 2. Image of 6- to 7-MeV neutrons from the same implosion. These neutrons have scattered at about 90° in the high-density fuel regions around the hot spot.

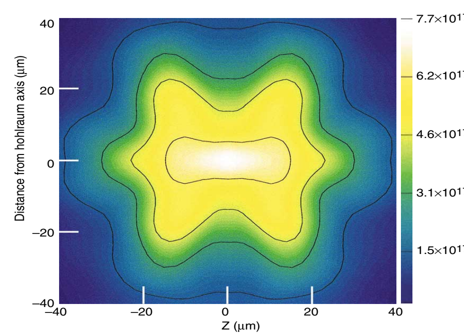


Figure 3. Image of 6- to 7-MeV neutrons from a simulation with the opposite sign of the P_6 perturbation.

For comments about content of the ***Bimonthly Update,*** contact Bruce A. Hammel (925) 422-3299.
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